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(72) KOCER, Bruce D., US
(72) O'CONNOR, James P., US
(72) BIHRER, Hans Otto, US
(71) THE BUDD COMPANY, US

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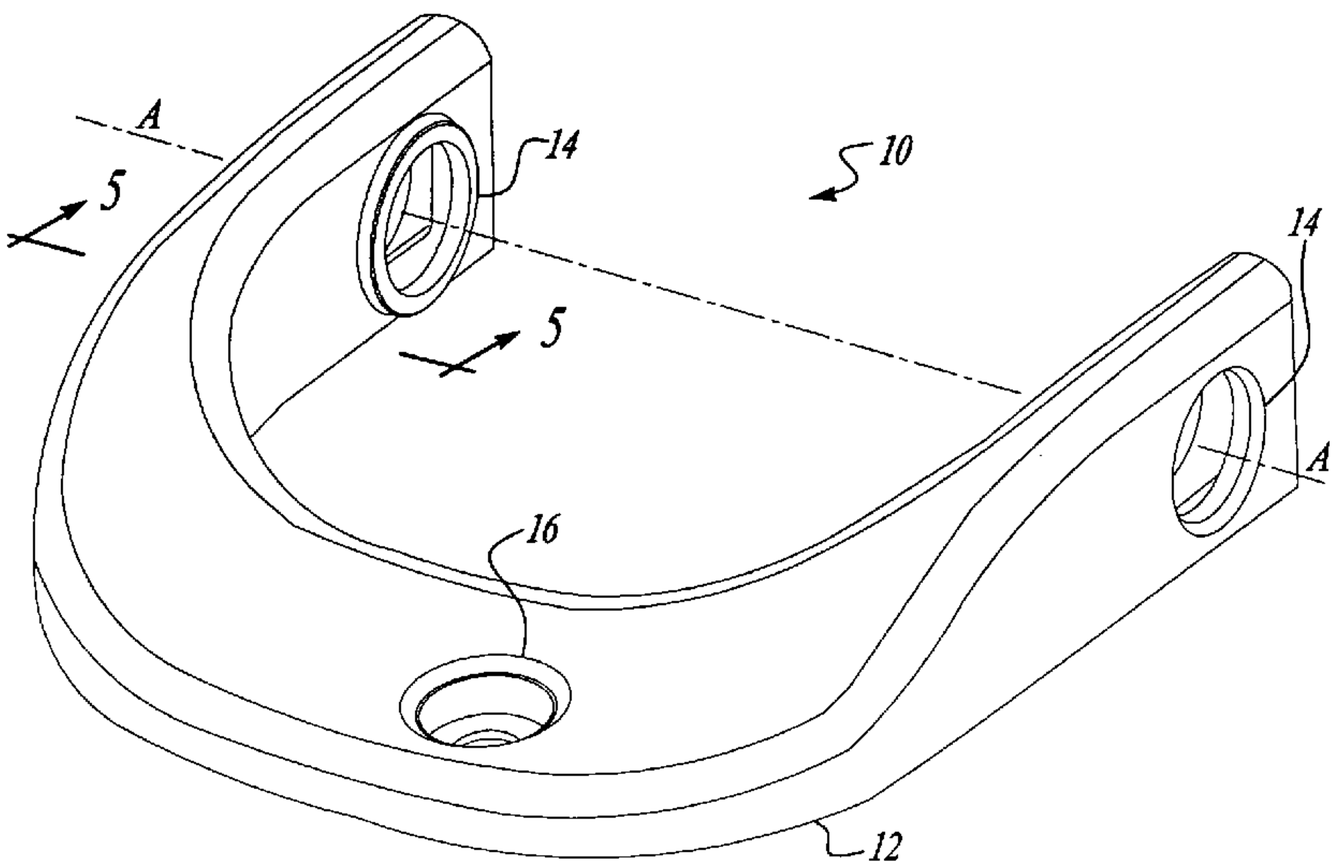
(54) **BRAS DE SUSPENSION HYDROFORME**
(54) **HYDROFORMED CONTROL ARM**



(57) A hydroformed control arm for a vehicle and a method of making the same is provided. The control arm includes a generally U-shaped member being hydroformed from a continuous, unitary tube. The generally U-shaped member includes varying cross-sectional areas along its length for improved structural integrity. The generally U-shaped member further includes a pair of pivot bores for enabling the control arm to pivot about a pivot axis. The U-shaped member still further including a ball joint cavity disposed near its apex for receiving a ball joint. The hydroformed control arm thereby eliminates the need for a ball joint bushing.

ABSTRACT OF THE DISCLOSURE

A hydroformed control arm for a vehicle and a method of making the same is provided. The control arm includes a generally U-shaped member being hydroformed from a continuous, unitary tube. The generally U-shaped member includes varying cross-sectional areas along its length for improved structural integrity. The generally U-shaped member further includes a pair of pivot bores for enabling the control arm to pivot about a pivot axis. The U-shaped member still further including a ball joint cavity disposed near its apex for receiving a ball joint. The hydroformed control arm thereby eliminates the need for a ball joint bushing.

Attorney Docket No. 2872S-000397

HYDROFORMED CONTROL ARM

CROSS-REFERENCE TO RELATED APPLICATION

This application is related to concurrently filed U.S. Patent Application Serial No. __/_____ entitled "MULTI-PIECE HYDROFORMING TOOL," which discloses common subject matter.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a control arm for a vehicle and, more particularly, to a control arm being hydroformed from a continuous, unitary tube and a method of making the same.

BACKGROUND AND SUMMARY OF THE INVENTION

Control arms are commonly used in vehicle wheel suspension systems to provide a stable connection between multiple suspension components. A traditional control arm **100** is shown in FIG. 1, wherein control arm **100** is pivotally connected between the axle housing **102** and the vehicle chassis **104**. The pivot connection allows for vertical displacement of the axle and wheel assembly. Traditional control arm **100** further includes a ball joint **106** pivotally coupled to a steering knuckle **108**. Still further, traditional control arm **100** includes at least one rubber bushing **110** connected to the ball joint **106**.

In operation, control arms must withstand extreme driving and braking torques created by the vehicle. To this end, it is necessary for control arms to be designed to maximize their structural integrity for improved tolerance of high vehicle loading forces caused by severe road damage, heavy braking, etc. It is also preferable for control arms to be designed to minimize the overall weight of the wheel suspension system.

As seen in FIG. 2, a cross-section of a typical control arm **112** is shown having a convoluted "hat-shaped" cross-section. Although the "hat-shaped" design is relatively simple to manufacture, it may not afford maximum structural integrity. Additionally, the hat-shaped design generally requires the use of bushing element **110** to properly receive ball joint **106**. Consequently, the "hat-shaped" design often fails to provide an optimal system.

Another typical control arm **114** is shown in FIG. 3 having a two-piece stamped construction, wherein the pieces **116**, **118** of the control arm are welded together. This design provides improved structural rigidity over the prior design shown in FIG. 2. However, like the prior design, the design shown in FIG. 3 requires the use of bushing element **110** to properly receive ball joint **106**. Moreover, this design fails to minimize the overall weight of the system.

Accordingly, there exists a need in the relevant art to provide a vehicle control arm capable of maximizing the structural integrity of the suspension system. Furthermore, the vehicle control arm should preferably minimize the weight of the wheel suspension system. Still further, there exists a need in the relevant art to improve manufacturing methods to increase production, without compromising product reliability.

According to the broad teachings of this invention, a control arm having an advantageous construction and method of manufacture, preferably by hydroforming, is provided.

According to a preferred embodiment of the present invention, a vehicle control arm is provided having a unitary, hydroformed, U-shaped tube. The vehicle control arm includes suspension interconnection means interconnecting the hydroformed tube and the vehicle wheel suspension. The interconnection means eliminate the need for a separate bushing element to support the ball joint, as required in the prior methods discussed above. A pair of pivot bores are further provided in U-shaped member to enable the hydroformed control arm to pivot about a pivot axis.

The present invention further provides a method of manufacturing the hydroformed control arm. The method of the preferred embodiment includes the steps of: (a) providing a die having a tooling cavity; (b) enclosing a tube within the tooling cavity of the die; (c) applying fluid pressure to an interior of the tube, the fluid pressure causing the walls of the tube to expand to closely conform to the shape of the tooling cavity, thereby forming a control arm having unitary construction.

According to a more preferred method of manufacturing the hydroformed control arm, the die includes a stationary lower die member and a movable upper die member. The die members together define the tooling cavity. Furthermore, the step of enclosing the tube within the tooling cavity specifically includes bending a generally straight tube to form generally S-shaped bends therein. The tube is then cut to form a plurality of generally U-shaped tubes. The U-shaped tubes are then enclosed within the die for hydroforming.

According to a still more preferred method of manufacturing the hydroformed control arm, a cavity is formed in the control arm by first maintaining the internal fluid pressure within the control arm. A forming tool, which is operably interconnected with the die, is positioned in contact with the side of the control arm. The forming tool is then driven into the side of the control arm to form an indentation. By increasing the fluid pressure within the interior of the control arm, while leaving the forming tool in place, the walls of the control arm are forced against the forming tool to form the cavity.

According to an even more preferred method of manufacturing the hydroformed control arm, an aperture is formed through the bottom portion of the cavity to allow a ball joint to extend therethrough. The aperture is formed in the cavity by extending a piercing tool, which is slidably disposed within the forming tool, through the bottom portion of the cavity while the forming tool remains within the cavity.

Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood however that the detailed description and specific examples, while indicating preferred embodiments of the invention, are intended for purposes of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. 1 is a perspective view of a wheel suspension system according to a prior art method of assembly;

FIG. 2 is a partial cross-sectional view of a prior art vehicle control arm;

FIG. 3 is a partial cross-sectional view of another prior art vehicle control arm;

FIG. 4 is a perspective view of a hydroformed control arm;

FIG. 5 is a cross-sectional view of FIG. 4, taken along line 5-5;

FIG. 6 is a top plan view of an elongated S-shaped constant-radius tube which is used as starting material to make the control arms;

FIG. 7 is a top plan view of a plurality of U-shaped round tubes which have been cut from the tube of FIG. 6;

FIG. 8 is a front view of a multi-piece hydroforming tool;

FIG. 9 is a cross-sectional view of FIG. 8, taken along line 9-9;

FIG. 10a is an exploded view, with portions in cross-section, of the multi-piece hydroforming tool;

FIG. 10b is a cross-sectional view of FIG. 10a, taken along line 10b-10b;

FIG. 11 is an exploded cross-sectional view of the multi-piece hydroforming tool in an opened position;

FIGS. 12-16 illustrate progressive steps in forming the ball joint cavity in the control arm; and

FIG. 17 is a cross-sectional view of the hydroformed control arm having a ball joint disposed in the ball joint cavity of the control arm.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description of the preferred embodiment is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. For example, the techniques disclosed herein may have utility in forming a wide variety of different parts.

Referring to the drawings, a hydroformed vehicle control arm **10**, and a method of making the same, is provided having a generally U-shaped member **12**. U-shaped member **12** is hydroformed from a single, constant-radius circular tube. As best seen in FIG. 4, hydroformed control arm **10** further includes a pair of pivot bores **14**. Pivot bores **14** are disposed on each end of generally U-shaped member **12** to enable hydroformed control arm **10** to pivot about an axis "A". Hydroformed control arm **10** further includes a ball joint cavity **16**. Ball joint cavity **16** is generally located at an apex of U-shaped member **12**. As will be described, ball joint cavity **16** provides means for retaining a ball joint **18** (FIG. 17) therein, without the need of the additional bushing element **110**. Ball joint **18** includes a base portion **18a** and a threaded portion **18b** to fixedly interconnect hydroformed control arm **10** and steering knuckle **108**.

As can be appreciated from FIGS. 4 and 5, hydroformed control arm **10** is preferably formed with varying cross-sectional areas to provide optimal

structural rigidity and performance. Furthermore, hydroformed control arm **10** is seamlessly constructed, thereby requiring no welding or stamping.

According to a preferred method of forming hydroformed control arm **10**, a straight tube having uniform wall thickness is first provided (not shown). By way of non-limiting example, the tube is approximately three (3) feet in length, two (2) inches in diameter, made of Steel 1008-1010 having a wall thickness of one-tenth (0.1) inch. More preferably, the tube is welded with scarfed weld seams. Generally straight tubes are readily available in the marketplace to facilitate mass production of hydroformed control arm **10**.

During manufacture, the generally straight tube is bent along its length to form a tube **20** having generally serpentine or S-shaped bends. Mandrels are preferably used during the bending process, if the combination of the tube wall thickness, tube material and bending radius is likely to cause wrinkling in S-shaped tube **20**. S-shaped tube **20** is then cut along a center line "B" to form a plurality of generally U-shaped tubes **22**, each tube having a constant radius "r", as seen in FIGS. 6 and 7.

Referring to FIG. 8 through 11, a multi-piece hydroforming tool **24** is shown having preferably four U-shaped cavities **26** disposed therein. As best seen in FIG. 8, multi-piece hydroforming tool **24** includes an upper die member **28** and a lower die member **30**. Upper die member **28** and lower die member **30** include opposed surfaces **32**, **34**, respectively. As best seen in FIG. 11, opposed surface **32** is disposed in a bottom portion **36** of upper die member **28**. Similarly, opposed surface **34** is disposed in a top portion **38** of lower die member **30**. Opposed surfaces

32, **34** are aligned and spaced to define U-shaped cavity **26** when bottom portion **36** of upper die member **28** contacts top portion **38** of lower die member **30**.

Still referring to FIGS. 10a, 10b, and 11, multi-piece hydroforming tool **24** further includes an injector manifold **40** secured to each U-shaped cavity **26** using a plurality of pre-stretched fasteners **41**. Injector manifold **42** delivers pressurized hydraulic fluid to U-shaped cavity **26**. Specifically, injector manifold **40** includes an inlet port **42** and a fluid aperture **44** extending through a pair of fluid nozzles **46**. Fluid aperture **44** defines fluid communication means between inlet port **42** and generally U-shaped cavity **26**.

As best seen in FIG. 9, multi-piece hydroforming tool **24** still further includes a hydraulic pressure source **48** in fluid communication with inlet port **42**. Hydraulic pressure source **48** provides hydraulic fluid **50** under extreme pressure, typically in the range of 15,000 psi to 90,000 psi, to each inlet port **42**.

Turning to FIGS. 10a, 10b, and 11, multi-piece hydroforming tool **24** includes a plurality of forming tools **52** provided in upper die member **28** of multi-piece hydroforming tool **24**. Each U-shaped cavity **26** includes at least one forming tool **52** and corresponding forming cylinder **53** for forming ball joint cavity **16** in hydroformed control arm **10**.

Similarly, multi-piece hydroforming tool **24** further includes an extruding device **54** for extruding pivot bores **14** in hydroformed control arm **10**. Specifically, each extruding device **54** includes a pair of outer extruding tools **54a** preferably disposed orthogonal to the ends of U-shaped cavity **26**. Each outer extruding tool **54a** is operably connected to corresponding outer extruding cylinder **54b**. In operation, outer extruding cylinder **54b** drives outer extruding tool **54a** into

the sides of U-shaped tube **12**, thereby forming an outer pivot bore depression. Similarly, each extruding device **54** further includes a pair of inner extruding tools **54c** preferably disposed orthogonal to the ends of U-shaped cavity **26** and further disposed coaxially oriented relative to outer extruding tools **54a**. Inner extruding tools **54c** are operably connected to a single inner extruding cylinder **54d**. In operation, inner pivot bore depressions are formed by retracting an inner extruding ram **54e** using inner extruding cylinder **54d**, thereby retracting inner extruding tools **54c**. Internal hydraulic pressure within U-shaped tube **12** causes a pair of inner pivot bore depression to be formed. After hydroforming, pivot bores **14** are formed by preferably drilling through inner and outer pivot bore depressions. However, it is anticipated that pivot bores **14** may also be formed by cutting or boring depending on tolerance requirements.

During operation of multi-piece hydroforming tool **24**, upper die member **28** is preferably moved from a closed position to an opened position. Generally U-shaped round tubes **22** are then placed in generally U-shaped cavities **26** of multi-piece hydroforming tool **24**. Generally U-shaped round tubes **22** are oriented such that the ends of generally U-shaped round tube **22** extend outward from U-shaped cavities **26**. Upper die member **28** is then moved to a closed position. A closed position is defined as the point when bottom portion **36** of upper die member **28** contacts top portion **38** of lower die member **30**. Injector manifolds **42** are then positioned to deliver pressurized hydraulic fluid **50** to U-shaped cavities **26**. Specifically, injector manifolds **42** are retained in multi-piece hydroforming tool **24** using a plurality of pre-scretched fasteners (not shown). The pre-scretched fasteners are preferably attached to lower die member **30**, thereby offsetting the hydroforming

fluid pressure. A pair of fluid nozzles **46** of injector manifold **42** are in fluid communication with the opened ends of generally U-shaped round tube **22**, thereby creating a fluid seal between fluid nozzle **46** and the ends of U-shaped round tube **22**.

Referring to FIG. 9, hydraulic pressure source **48** forces hydraulic fluid **50** into an interior volume of generally U-shaped round tube **22** such that U-shaped round tube **22** expands to closely conform to the shape of opposed surfaces **32**, **34** of U-shaped cavity **26**. This technique is known as hydroforming.

Referring to FIGS. 12 through 16, a method of forming ball joint cavity **16** in hydroformed control arm **10** is provided. As seen in FIG. 11 and as noted above, hydraulic pressure source **48** provides hydraulic fluid **50** at extreme pressure so as to expand U-shaped round tube **22** to conform with opposed surfaces **32**, **34** of multi-piece hydroforming tool **24**. As best seen in FIG. 13, forming tool **52** extends from opposed surface **32** of upper die member **28** and applies pressure to form a generally sloping depression **56** in hydroformed control arm **10**. This step allows uniform stretching of the material of hydroformed control arm **10**. The uniform stretching of the material minimizes possible stress fractures formed during manufacture. Forming tool **52** continues to form sloping depression **56** until a first interior wall **58** of hydroformed control arm **10** contacts an opposing second interior wall **60**. The contact prevents further movement of forming tool **52**.

As best seen in FIG. 15, once forming tool **52** has completely formed sloping depression **56**, the pressure of hydraulic fluid **50** is increased to force the walls of the tube defining sloping depression **56** to generally conform to the shape of forming tool **52**. Generally vertical walls **62** of ball joint cavity **16** are thereby

formed. As can be appreciated from FIG. 15, generally vertical wall **62** include a draft angle "α" to allow for improved tooling of hydroformed control arm **10**.

Without intending to be limited by example, a draft angle of approximately three to four degrees (3-4°) from vertical has been found to be sufficient.

Referring to FIGS. 11-16, a piercing tool **64** is shown as being slidably received within a bore **66** of each forming tool **52**. Piercing tool **64** is further shown operably connected to a mechanical device or piercing cylinder **65**. Piercing tool **64** creates an aperture **68** in a bottom portion **70** of ball joint cavity **16**. Specifically, piercing cylinder **65** forces piercing tool **64** through first interior wall **58** and second interior wall **60** while forming tool **52** remains in ball joint cavity **16**. During the piercing process, piercing tool **64** is received within a corresponding receiving chamber **72** of lower die member **30**. Receiving chamber **72** is created by retracting a receiving tool **74** using a receiving tool cylinder **76**. This method enables opposed surface **34** to remain flat during hydroforming of U-shaped member **12**, yet accommodate an end of piercing tool **64** during the piercing operation. A completed hydroformed control arm **10** is then removed from generally U-shaped cavity **26** of multi-piece hydroforming tool **24**.

Referring to FIG. 17, ball joint **18** is shown disposed in ball joint cavity **16** of hydroformed control arm **10**. Preferably, the outer diameter of ball joint **18** is greater than the inner diameter of ball joint cavity **16**, thereby creating a press fit connection between ball joint **18** and ball joint cavity **16**. The press fit connection eliminates the need to provide the additional bushing element **110** disposed between

hydroformed control arm **10** and the ball joint **18** of the prior art constructions discussed above.

It should be appreciated that the multi-piece hydroforming tool of the present invention enables multiple control arms to be hydroformed simultaneously. However, unlike the prior art method, the present invention hydroforms multiple control arms independently in a single die. This method of hydroforming minimizes the need to discard all of the hydroformed control arms if one hydroformed control arm is found to be defective. Furthermore, it should be appreciated that unlike the prior art methods of making a control arm, the present inventions provides a continuous, unitary hydroformed control arm. The unitary construction of the control arm is believed to improve the structural integrity of the control arm, thereby providing a more optimal design.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

CLAIMS

What is claimed is:

1. A control arm for a vehicle, said control arm comprising:

a hydroformed unitary tube being generally U-shaped; and

suspension interconnection means interconnecting said hydroformed tube and the vehicle.

2. The control arm according to Claim 1, further comprising:

a pair of pivot bores extending through said hydroformed tube.

3. The control arm according to Claim 2 wherein said suspension interconnection means comprises:

a ball joint for threadedly interconnecting said hydroformed tube and a steering knuckle of the vehicle;

at least one cavity disposed in said hydroformed tube for receiving a base portion of said ball joint therein, said at least one cavity having a base portion and a side portion; and

an aperture extending through said base portion of said at least one cavity for receiving a threaded portion of said ball joint therethrough.

4. The control arm according to Claim 1 wherein said hydroformed tube includes varying cross-sectional areas along its length.

5. A control arm for a vehicle, said control arm comprising:

a hydroformed seamless member; and

at least one interconnecting device for interconnecting said hydroformed seamless member and the vehicle.

6. The control arm according to Claim 5, further comprising:

a pair of pivot bores extending through said hydroformed member.

7. The control arm according to Claim 6 wherein said interconnecting device comprises:

a ball joint for threadedly interconnecting said hydroformed member and the vehicle;

at least one cavity disposed in said hydroformed member for receiving a base portion of said ball joint therein, said at least one cavity having a base portion and a side portion; and

an aperture extending through said base portion of said at least one cavity for receiving a threaded portion of said ball joint therethrough.

8. The control arm according to Claim 7 wherein said hydroformed member includes varying cross-sectional areas along its length.

9. A method of hydroforming a control arm of a vehicle, said method comprising the steps of:

providing a die having a tooling cavity;

enclosing a tube within said tooling cavity of said die;

applying fluid pressure to an interior of said tube, said fluid pressure causing the walls of said tube to expand to closely conform to the shape of said tooling cavity, thereby forming a control arm having unitary construction.

10. The method according to Claim 9 wherein said die further includes upper and lower die members, at least one of said die members being movable between opened and closed positions, said upper and lower die members together definf said tooling cavity.

11. The method according to Claim 10 wherein the step of enclosing a tube within said tooling cavity of said die includes the steps of:

providing a generally straight tube;

bending said tube to form generally S-shaped bends therein;

cutting said tube to form a plurality of individual generally U-shaped tubes;

moving said movable die member into said opened position;

placing said U-shaped tube within said tooling cavity of said die; and

moving said movable die member into said closed position, thereby retaining and enclosing said U-shaped tube within said tooling cavity of said die.

12. The method according to Claim 11, further comprising:

maintaining said hydraulic pressure within said interior of the control arm;

providing a forming tool being operably interconnected with said die for forming a cavity in the control arm;

positioning said forming tool in contact with a side of the control arm;

driving said forming tool into said side of the control arm thereby forming an indentation therein; and

increasing said hydraulic pressure within said interior of the control arm while leaving said forming tool in place, said hydraulic pressure moving the walls of the control arm against said forming tool thereby forming said cavity therein.

13. The method according to Claim 12, further comprising:

providing a piercing tool slidably disposed within said forming tool for piercing an aperture through a bottom portion of said cavity of the control arm; and

extending said piercing tool through said bottom portion of said cavity while said forming tool remains within said cavity, thereby forming said aperture through said bottom portion of said cavity.

14. The method according to Claim 13, further comprising:

providing a ball joint having a base portion and a threaded portion; and

disposing said base portion of said ball joint within said cavity of the control arm, thereby extending said threaded portion through said aperture of said cavity.

15. The method according to Claim 14 wherein an outer diameter of said ball joint is greater than an inner diameter of said cavity of the control arm and wherein said ball joint is pressed into said cavity of the control arm such that said ball joint is frictionally retained within said cavity of the control arm.

16. The method according to Claim 9 wherein said die includes a plurality of said generally U-shaped cavities for forming a plurality of control arms independently.

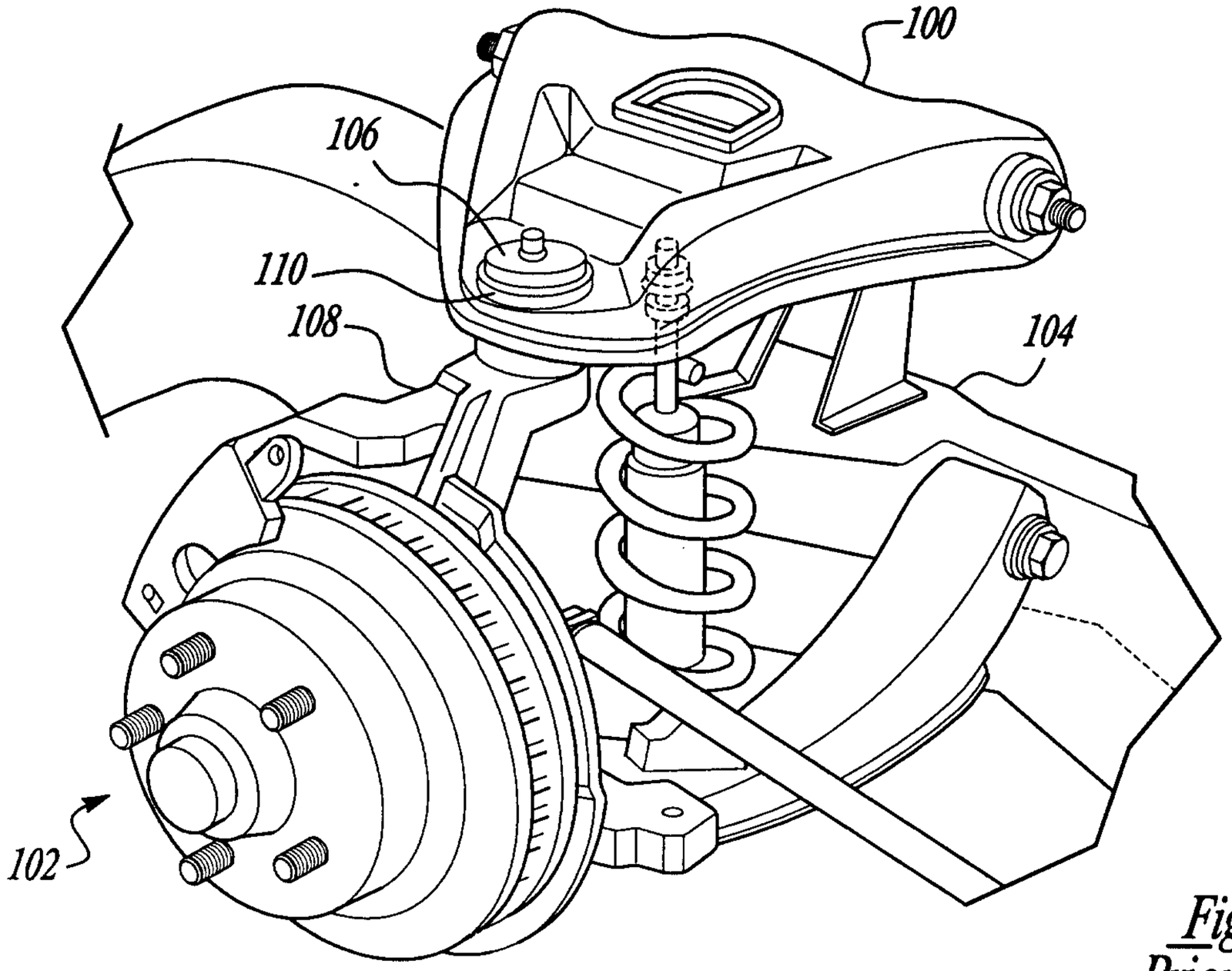


Fig-1
Prior Art

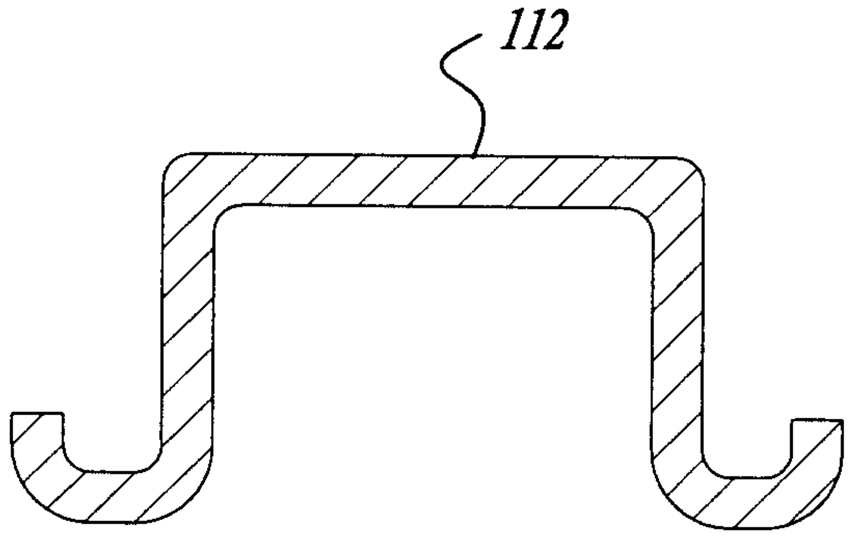


Fig-2
Prior Art

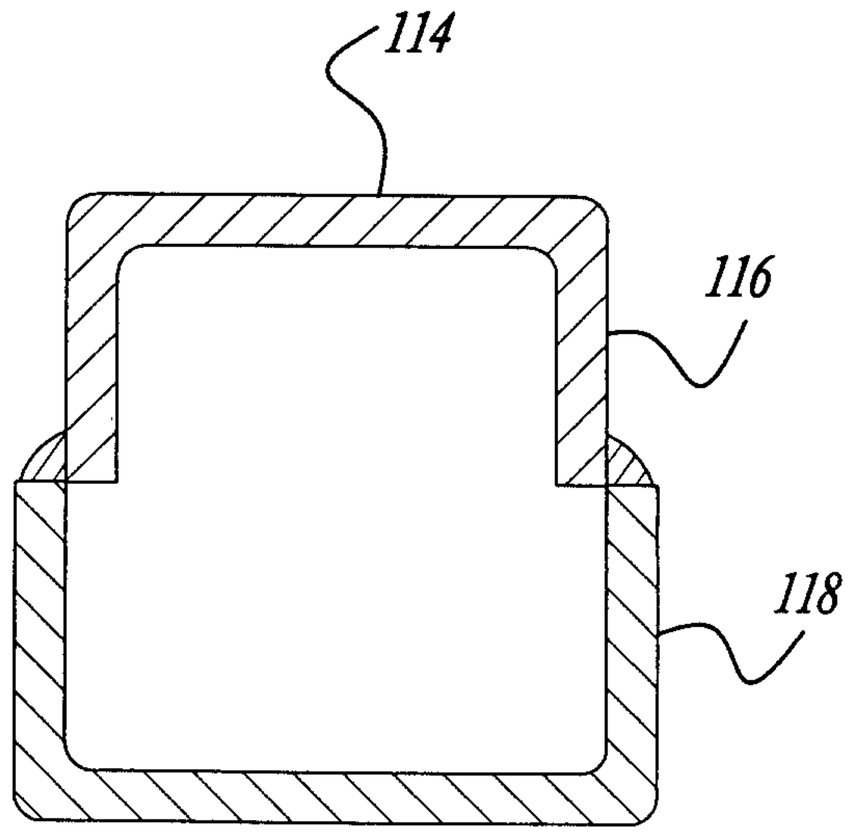


Fig-3
Prior Art

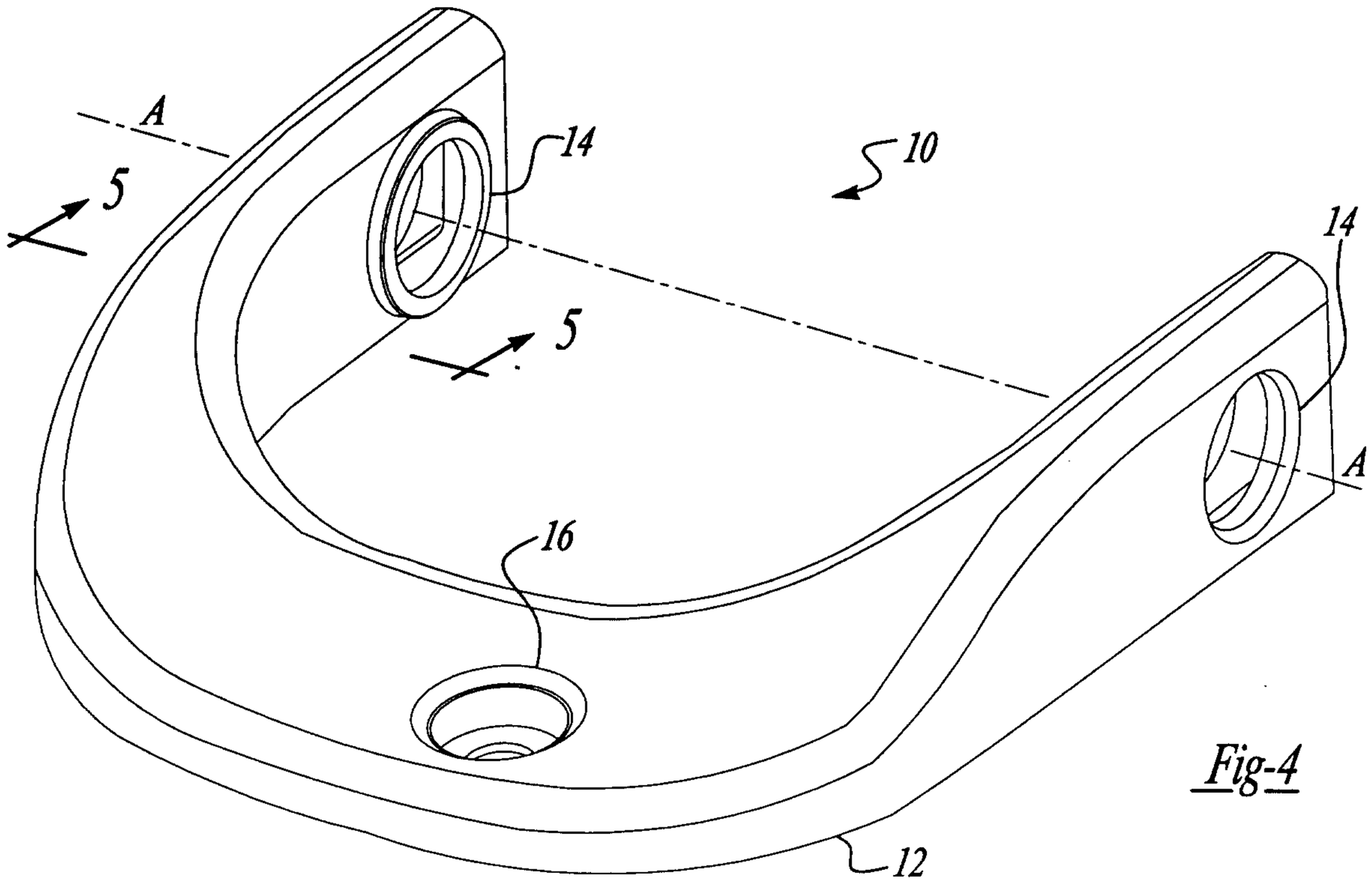


Fig-4

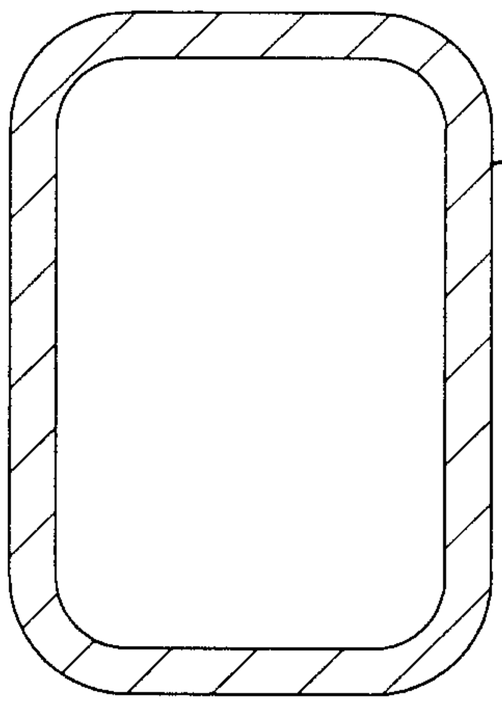


Fig-5

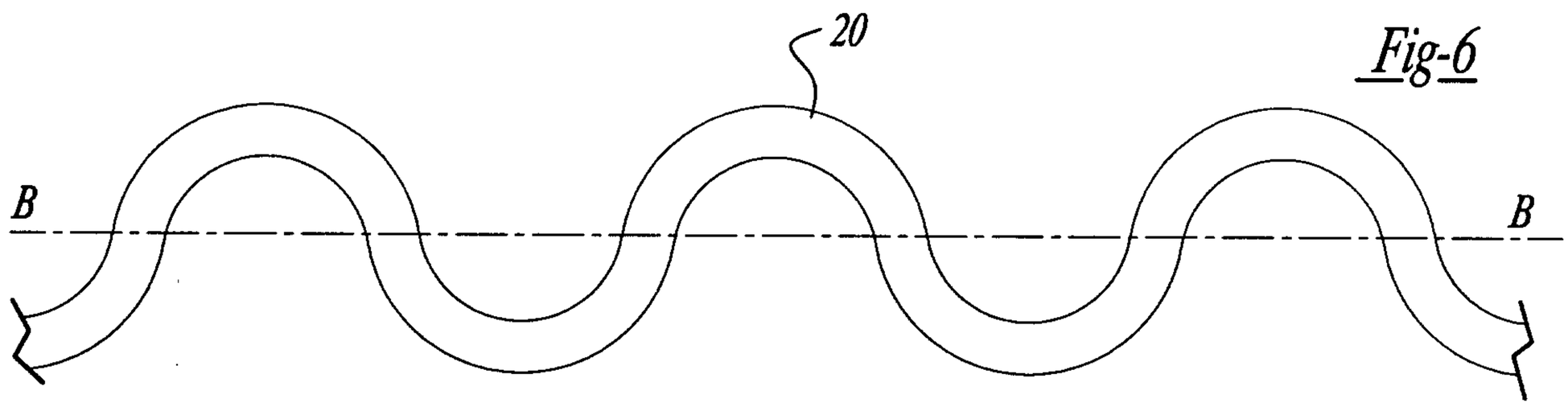


Fig-6

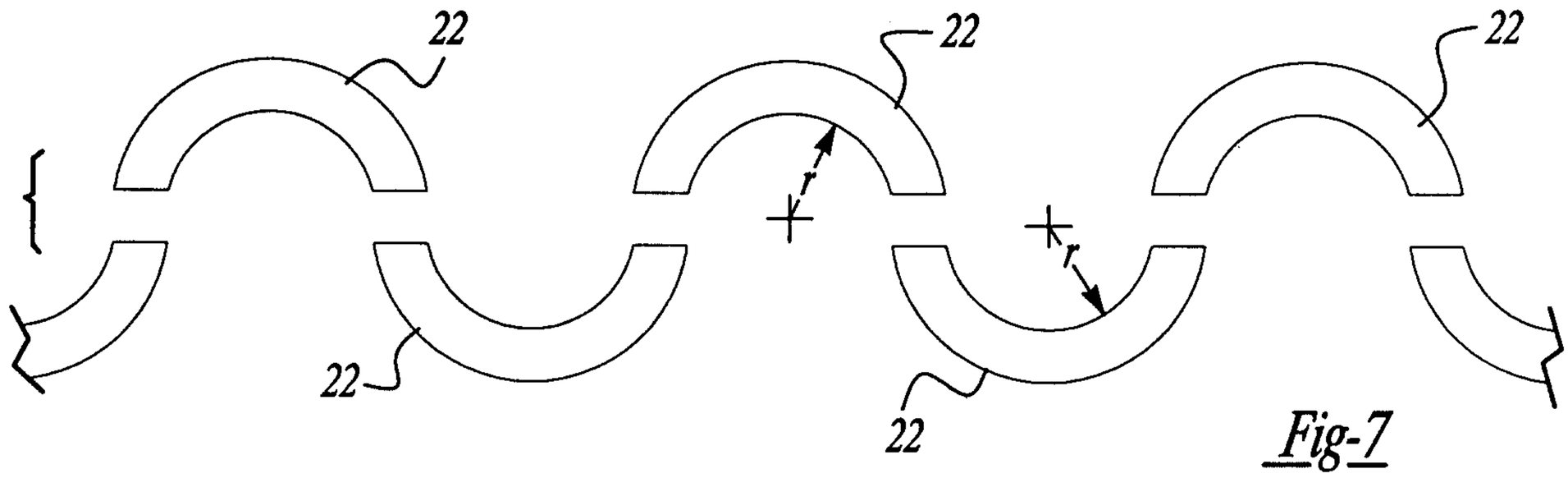


Fig-7

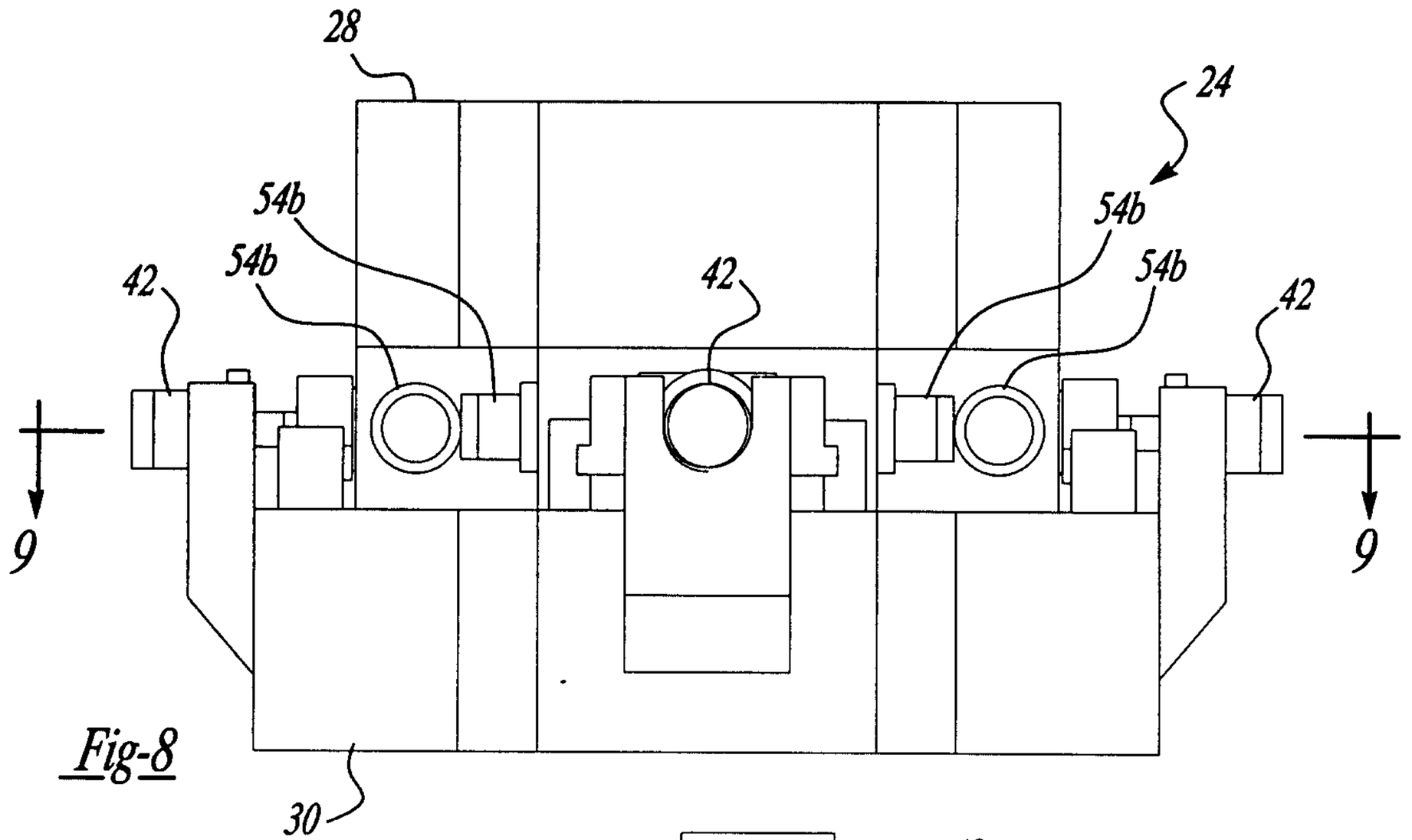
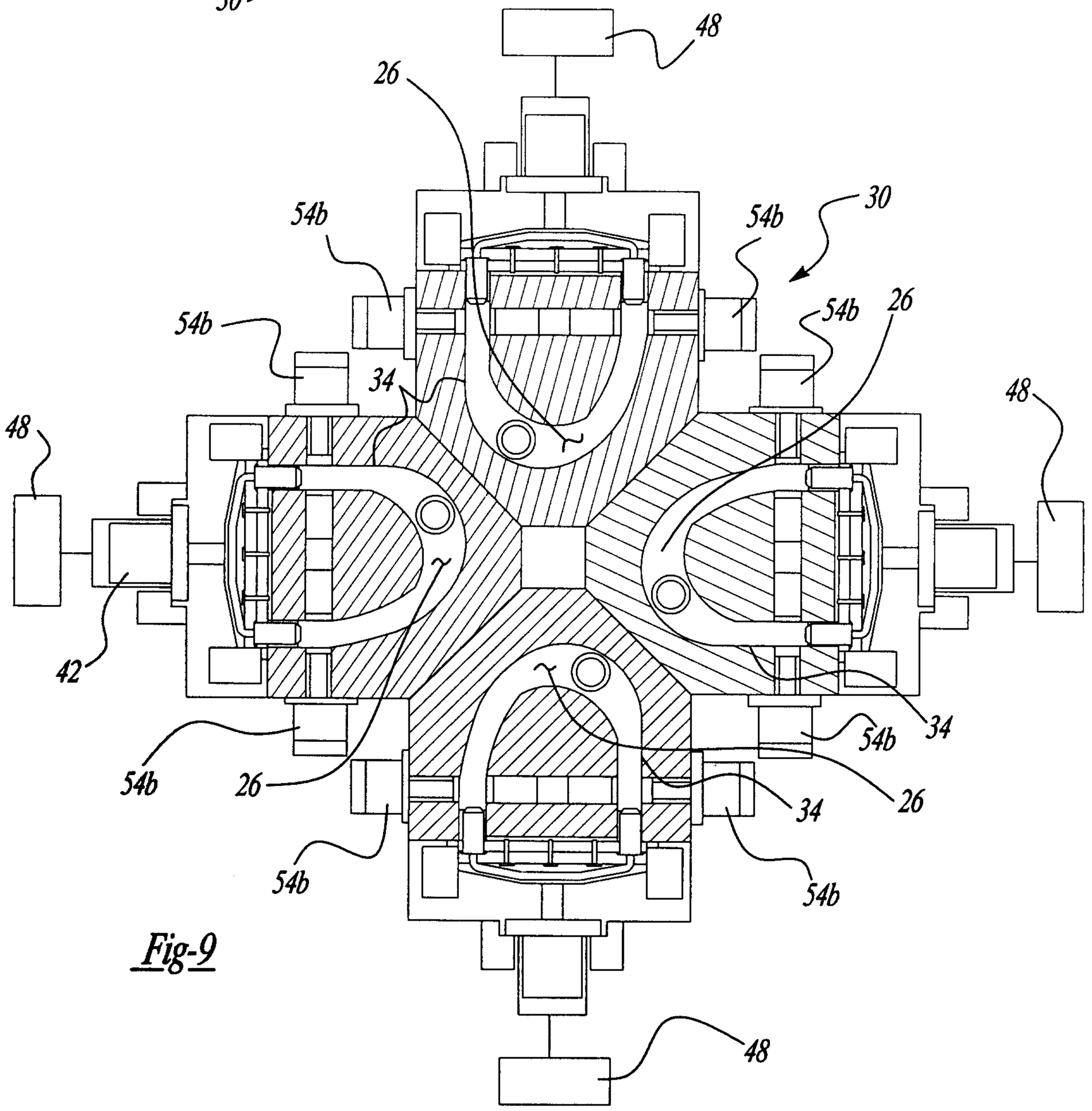

28
24
54b
54b
54b
54b
42
42
42
9
9
30

Fig-8


48
26
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48

Fig-9

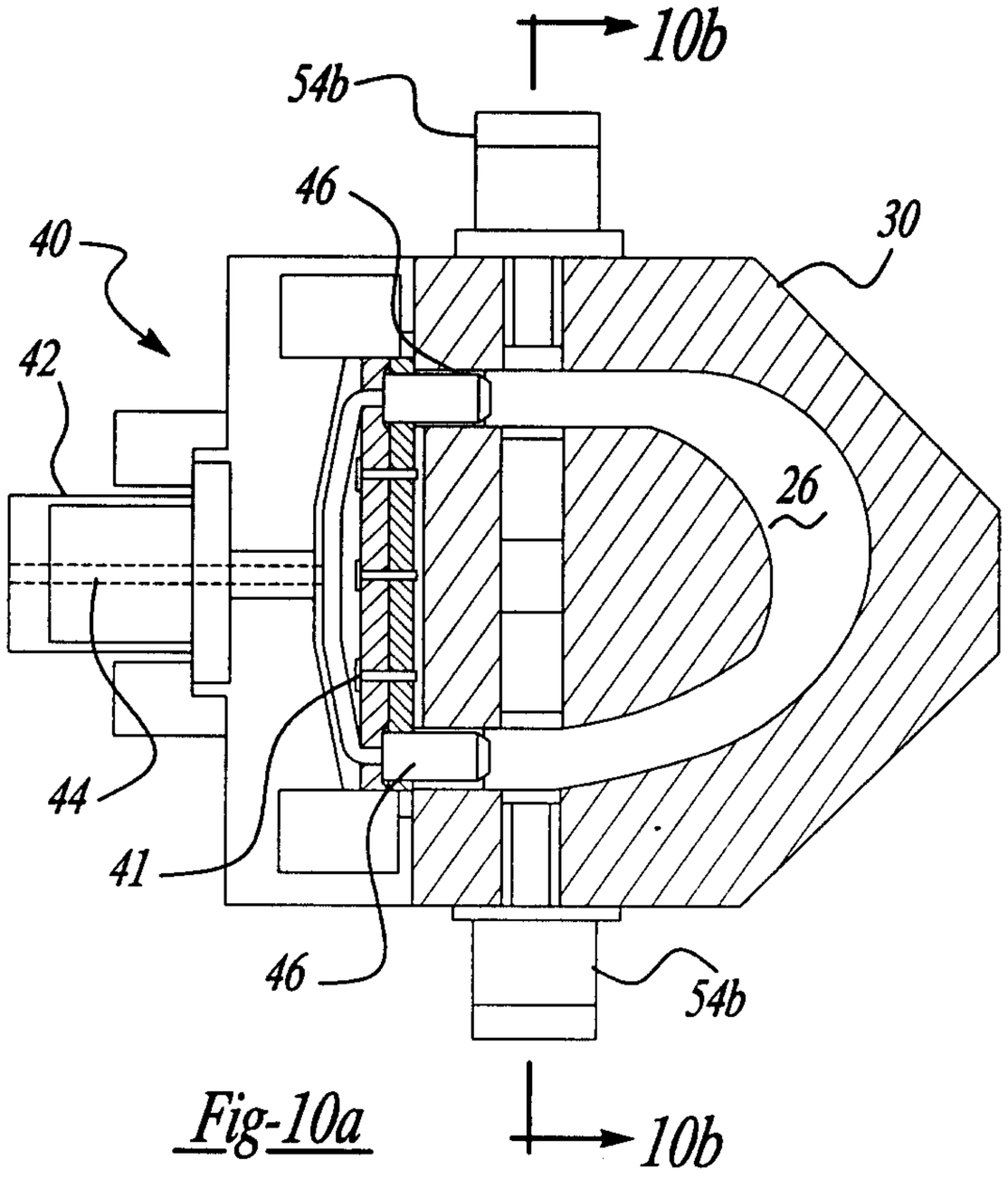

Fig-10a

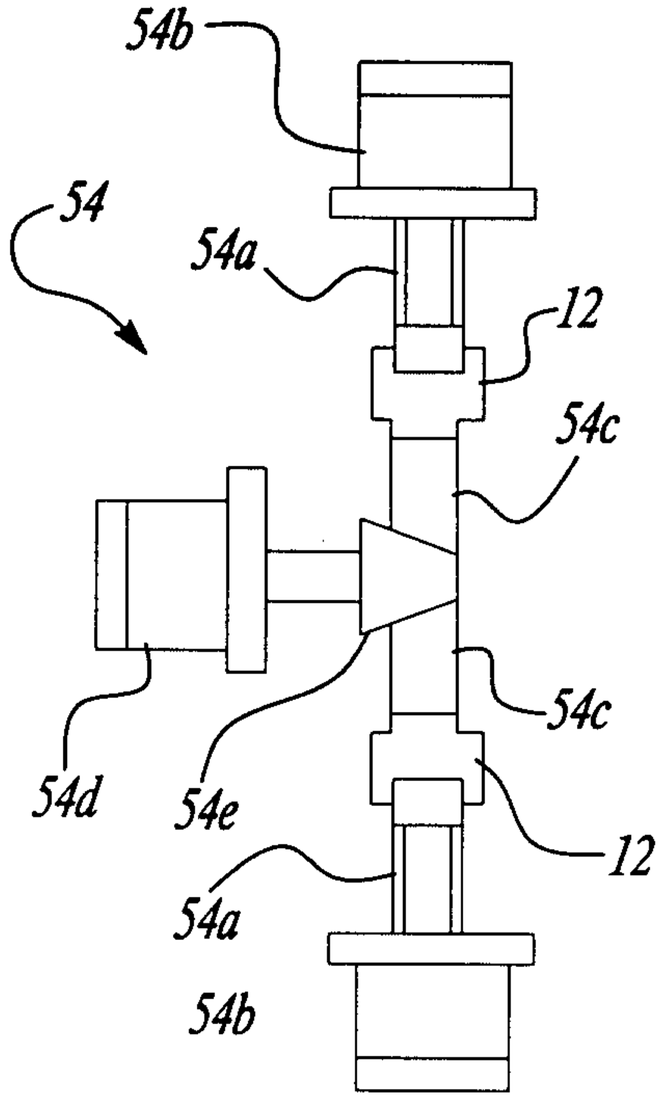

Fig-10b

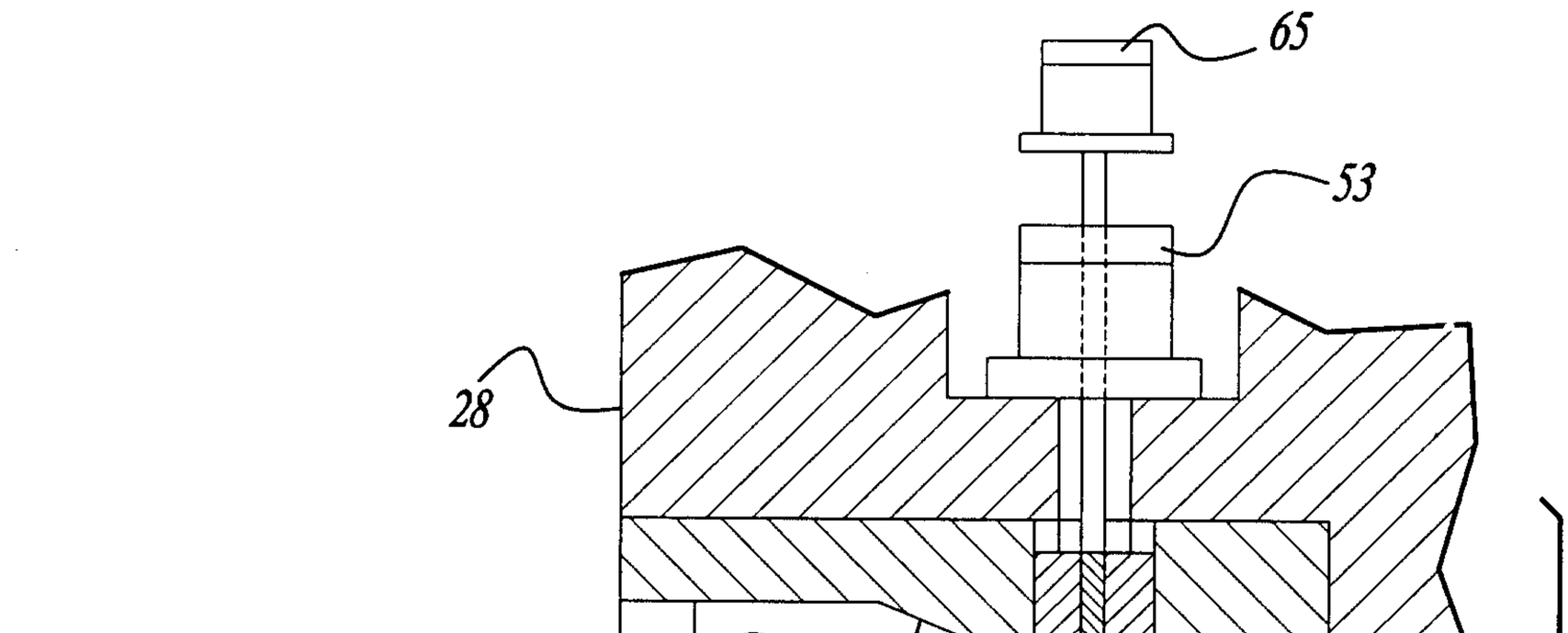

Fig-11

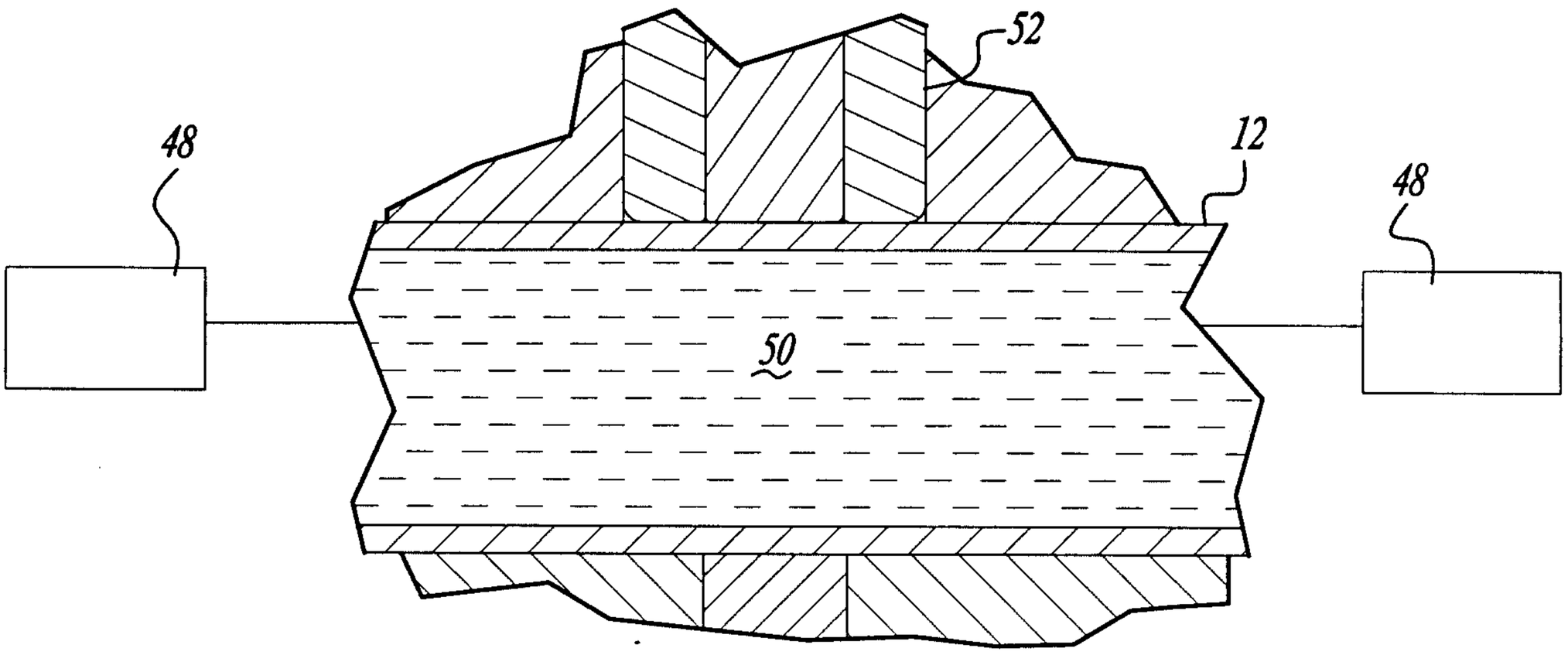

Fig-12

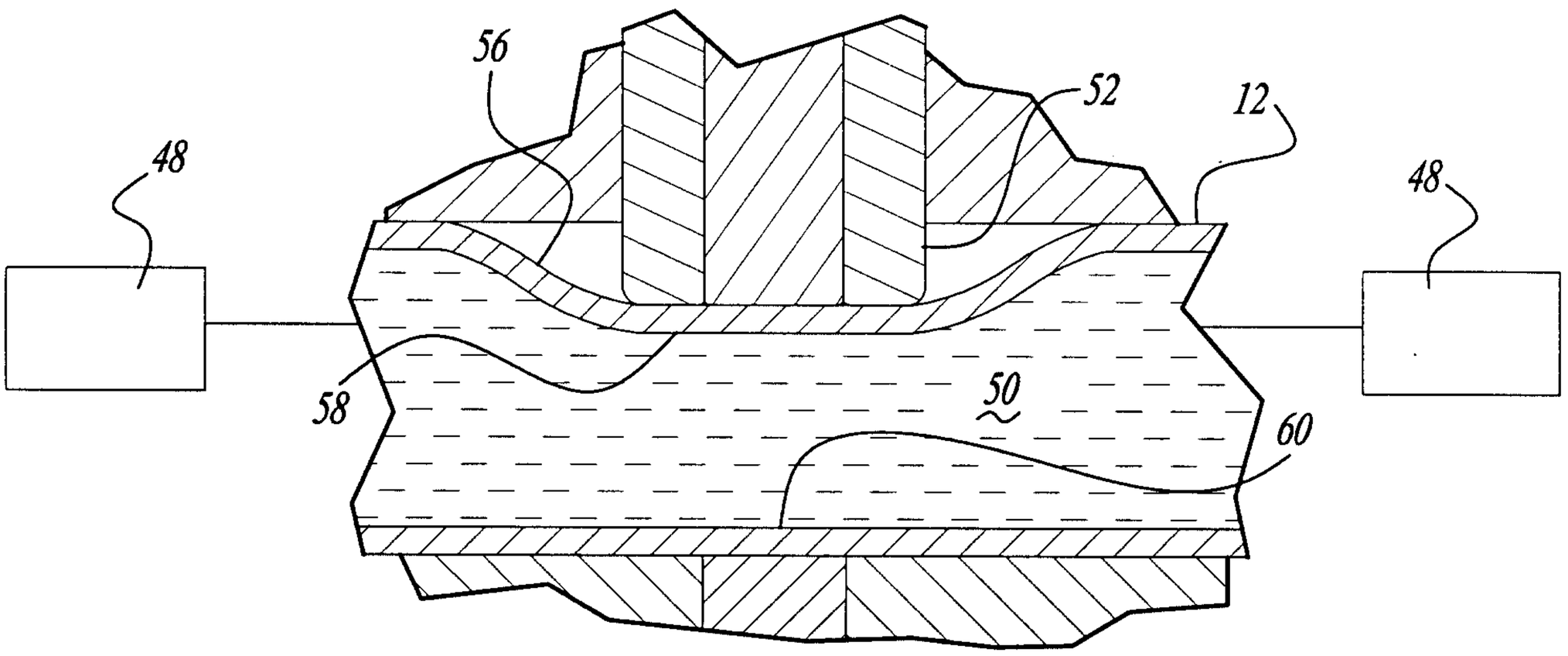

Fig-13

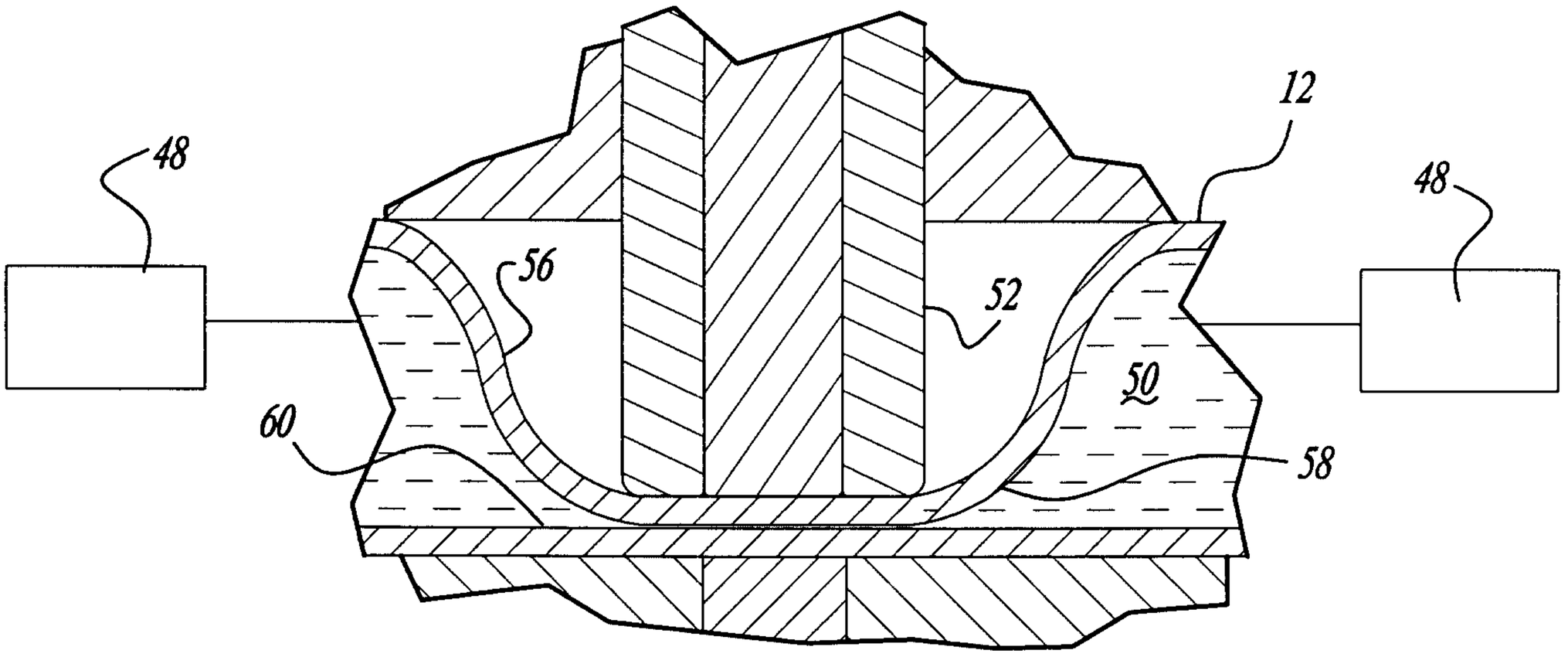

Fig-14

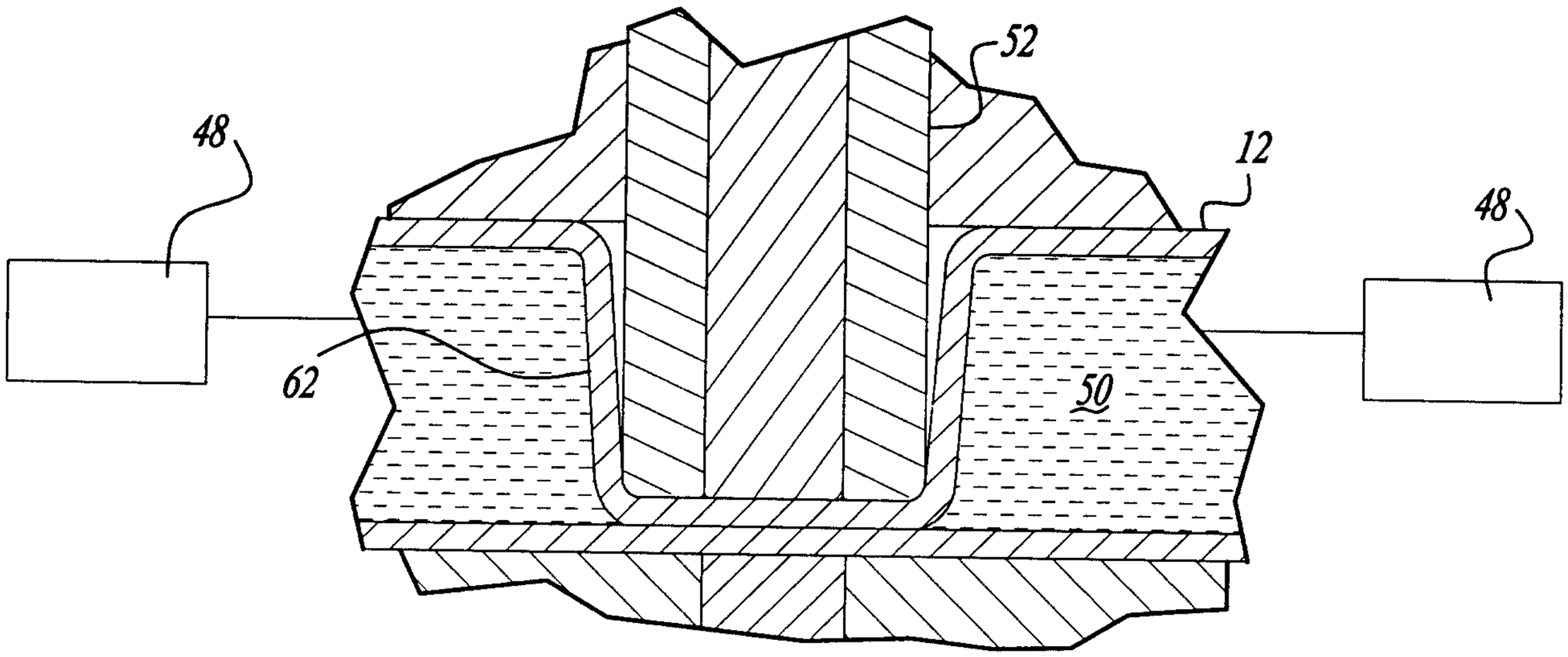

Fig-15

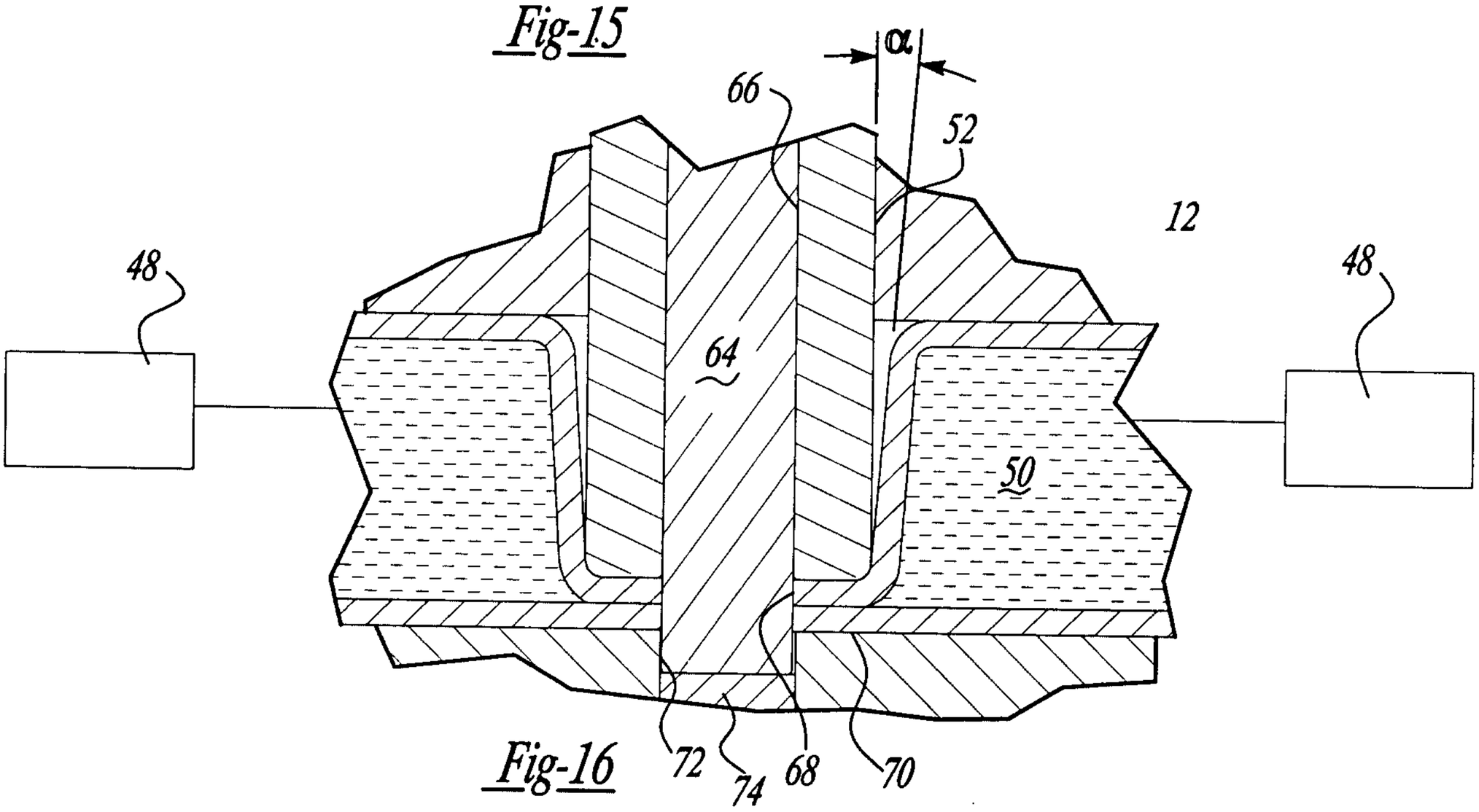

Fig-16

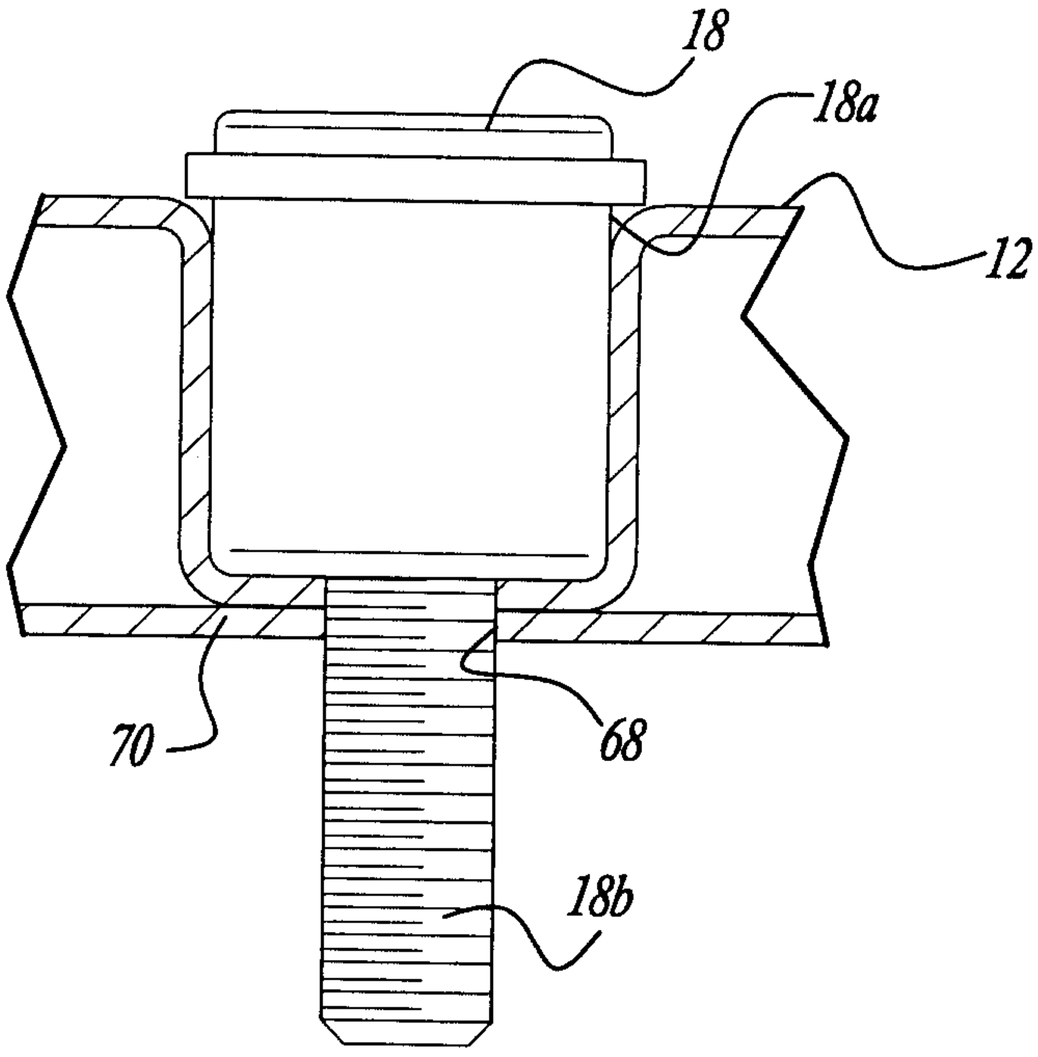

Fig-17